Sod-Seeding in the Aspen Parkland

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The possibility of increasing pasture productivity by sod-seeding tame forages directly into poor condition pastures of the Aspen Parkland region of Western Canada was first reported in 1967 (Bowes and Friesen 1967). Bowes and Friesen used paraquat to reduce competition from the existing vegetation one day after alfalfa was seeded directly into a bluegrass sod. The introduction of glyphosate which has no apparent residue, the translocates and provides effective control of many broad leaf and grass species makes the herbicide an excellent candidate for general vegetation suppression before sod-seeding (Baird et al. 1971). In Saskatchewan, glyphosate has successfully suppressed the resident vegetation, reducing it's competition so tame forage species could be sod-seeded (Waddington and Bowren 1976).

There are several advantages of using sod-seeding to increase pasture production rather than relying on the traditional method of breaking, summerfallowing and then reseeding. Sod-seeding is more environmentally friendly because the soil is not exposed to potential water and wind erosion. Further, the number of passes of field equipment and the associated costs of operating the equipment may be less with sod-seeding than with conventional pasture improvement methods. Finally, sod-seeding may reduce the length of the grazing restricions required to permit forage establishment, compared to the traditional method for pasture improvement.

The objective of this study was to compare herbage production and economic returns following sod-seeding, without suppression, and with the use of chemical and mechanical methods to reduce competition from the resident vegetation before alfalfa and tame grass species were sod-seeded into low yielding, poor condition pastures in the Aspen Parkland of north-central Saskatchewan.

MATERIALS AND METHODS

The project was located 193 km northeast of Regina, Saskatchewan in the Beaver Hills. The area selected for the experiments was in the aspen grove vegetation zone (Rowe 1972). The experimental site was cleared of mature aspen and balsam poplar trees during the winter of 1957 with a ball and chain. In subsequent years, there was severe woody regrowth, when native grasses and forbs were invading the mechanically treated areas. Further control of the woody regrowth was required and in 1964 the area was bulldozed and roller chopped. This series of mechanical treatments failed to control the woody regrowth, and in 1966 the area was treated with 2,4-D applied at 2.2 kg ha^{-1}.

During and after the mechanical and chemical improvement techniques, the area was grazed by beef cattle using a season long grazing system. When the experiments were started in 1980, fowl-meadow bluegrass (Poa palustris L.), and Kentucky bluegrass (Poa pratensis L.) were the dominant grasses. Soil texture was a loam

Table 1. Precipitation and temperature recorded for the year and the April to June growing season during 1980-88 for weather stations located at Kelliher and Yorkton, Saskatchewan

	Precipitation†				Temperature†			
Year	Jan.-Dec.	%‡ Change	Apr.-June	% Change	Apr.-Oct	% Change	Apr.-June	% Change
	(mm)		(mm)		(°C)		(°C)	
1980	394	-15	61	-58	12.3	1.2	12.6	3.4
1981	567	22	188	31	11.8	0.7	9.8	0.6
1982	433	-6	102	-29	10.8	-0.3	8.5	-0.7
1983	536	16	185	28	11.7	0.6	7.3	-1.9
1984	461	0	155	8	11.2	0.2	10.2	1.0
1985	442	-5	176	22	10.3	-0.8	9.7	0.5
1986	429	-7	151	5	11.0	-0.1	10.0	0.8
1987	383	-17	117	-19	12.1	1.0	12.6	3.4
1988	422	-9	141	-2	12.3	1.3	12.6	3.4
Normal	463		144					

† Canadian Climate Normals for 1951-80.
‡ % change from Canadian Climate Normals for 1951-80.

within the Waitville association (Mitchell et al. 1944). Precipitation and air temperature were recorded at two weather stations, located in opposite directions from the experimental site, at Kelliher and Yorkton, Saskatchewan (Table 1) Anonymous 1981).

Similar experiments were started during the spring of four consecutive years. The experiments were designed as completely randomized blocks, replicated four times, with an individual plot size of 16 m^2. The treatments were: (1) control, (2) glyphosate applied at 2.5 kg(ai) ha^{-1} (GLY2.5), (3) glyphosate + ammonium sulfate applied at 2.0 + 1.7 kg(ai) ha^{-1} + 0.5% Agsurf (GLY2.0NHS1.7), (4) glyphosate + ammonium sulfate applied at 1.0 + 1.7 kg(ai) ha^{-1} + 0.5% Agsurf (GLY1.0NHS1.7)and (5) rotovation. The rotovation treatment consisted of 3 to 4 passes of an 8 hp rotovator. Dates for treatment application are shown in Table 2. Herbicides were applied in 225 L ha^{-1} of water with a 4 nozzle, compressed air, knapsack sprayer.

Alfalfa was seeded directly into the existing sod with a triple-disc rangeland seeder. In 1979 and 1980 crested wheatgrass, and in 1981 and 1982 brome, was seeded in the same row with alfalfa. The seeding rate for each species was 80 seeds per meter-row. The triple-disc drill seeded five rows at 30 cm spacing. Forage species

Table 2. Dates for herbicide application, sod-seeding, alfalfa and brome plant counts, and forage sampling

	Experiment number			
	1	2	3	4
Year experiment started	1980	1981	1982	1983
Herbicide application	22 May	11 June	10 June	15 June
Sod-seeding	22 May	11 June	10 June	15 June
Plant counts				
First year	12 Aug.	13 Aug.	14 July	4 Aug.
Second year	25 June	29 June	17 June	27 June
Third year	29 June	17 June	26 June	21 June
Fourth year	17 June	26 June	21 June	25 June
Fifth year	26 June	20 June	24 June	6 Aug.
Sixth year	20 June	24 June	2 July	7 July
Forage clipping				
Third year	7 July	14 July	11 July	23 July
Fourth year	14 July	11 July	22 July	23 July
Fifth year	11 July	16 July	22 July	6 Aug.
Sixth year	16 July	22 July	6 Aug.	8 July

were sod-seeded through all plots, including the control. Dates for sod-seeding are shown in Table 2.

Forage establishment was measured by recording the number of plants per 2-meter row. Three years after sod-seeding, forage samples were clipped from 4 quadrats, each 625 cm^2. In 1980 and 1981, forage samples were hand separated into grass, alfalfa, forbs, and woody plants. Crested wheatgrass establishment was poor in 1980 and 1981, so brome was seeded in 1982 and 1983. For the experiments which were started in 1982 and 1983, grasses were separated into brome and other grass species. The majority of the other grasses were bluegrass. Sampling dates are shown in Table 2. The oven dry weight for each species group was recorded after drying the samples for 48 hr in a forced air oven set at 95 °C.

The economic performance of the pasture improvement treatments were compared using a capital budgeting framework (Doll and Orazem 1978). This approach involved computing the net present value (NPV) of the annual forage returns and establishment costs for each treatment, replicate, and

Table 3. Summary of selected economic parameters

	Price/Cost level			
	Low	Medium	High	Units
Standing forage				
Alfalfa	25.0	50.0	75.0	$\$ t^{-1}$ DM
Crested wheatgrass	18.5	37.0	55.5	$\$ t^{-1}$ DM
Brome	19.5	39.0	58.5	$\$ t^{-1}$ DM
Bluegrass	19.0	38.0	57.0	$\$ t^{-1}$ DM
Forbs	2.5	5.0	7.5	$\$ t^{-1}$ DM
Chemicals				
Glyphosate		36.24		$\$ kg^{-1}$ ai
NH_4SO_4		0.22		$\$ kg^{-1}$
Agsurf		5.69		$\$ L^{-1}$
Machine operations				
Disc plow		36.70		$\$ ha^{-1}$
Tandem disc		15.48		$\$ ha^{-1}$
Harrow pack		5.90		$\$ ha^{-1}$
Double dics plant		21.53		$\$ ha^{-1}$
Zero till plant		34.97		$\$ ha^{-1}$
Spray and water hauling		7.50		$\$ ha^{-1}$
Discount rate		5.0		%

experiment based on the following formula:

$$NPV_i = \sum_{t=1}^{T} (A_{it}*V_{at} + G_{it}*V_{gt} + N_{it}*V_{nt} + F_{it}*V_{ft} - C_{it})*(1 + r)^{-t}$$

where:
A = dry matter yield of alfalfa forage (kg ha^{-1}) consumable by beef cattle in treatment i and year t; G = consumable dry matter yield of tame grass (kg ha^{-1}); N = consumable dry matter yield of native grasses (kg ha^{-1}); F = consumable dry matter yield of forbs (kg ha^{-1}); V_a = value of alfalfa ($ kg^{-1} DM); V_g = value of tame grass ($ kg^{-1} DM); V_n = value of native grasses ($ kg^{-1} DM); V_f = value of forbs ($ kg^{-1} DM); C = cost of seed, herbicides, and machine operations ($ ha^{-1}); r = discount rate (%), and; T = length of study period (years).

The most profitable pasture improvement treatment within an experiment is the one that provides the highest positive NPV. However, the overall profitability of sod-seeding cannot be determined from this study alone because a true check treatment (i.e., no seeding of improved forages) was not included in the experiments.

The analysis was conducted using 1990 costs for forage seed, herbicides, and machine operations (Saskatchewan Agriculture and Food 1990; University of Saskatchewan 1990) (Table 3). For the rotovate treatments, machine costs were assumed to be equivalent to the costs of one operation of a heavy-duty disc plow, followed by two lighter discings, harrow packing, and seeding with a conventional double-disc press drill. Since the test areas were excluded from grazing by beef cattle, the value of the harvested forages were taken as being equivalent to that of standing hay (expressed on a dry weight basis). The relative feed values of alfalfa, crested wheatgrass, brome, and bluegrass (i.e., the main species of native grass) (Table 3) were estimated based on average nutrient compositions obtained from the literature (Perry 1980) and the following relationship provided by the Saskatchewan Feed Testing Laboratory (personal communication):

$$V_j = 2.57*CP_j + 0.58*TN_j + 3.14*CA_j +32.55*PH_j$$

where:
V = feed value of forage type j ($ t^{-1} DM); CP = crude protein content (%); TN = total digestible nutrients (%); CA = calcium content (%); and PH = phosphorus content (%).

The feed value of forbs was taken as 10% of that for alfalfa. Because of the need to maintain pasture plants in a productive state (Smoliak et al. 1988), a carryover of 25% of the total annual forage production was assumed in the analysis. Further, to capture pasture productivity improvements beyond the end of the 4-year study period, it was assumed that the mean yield for each species group and treatment would: i) persist at a constant level for 5 years into the future, ii) persist at a constant level for 10 years into the future, iii) decline linearly over 5 years into the future, and iv) decline linearly over 10 years into the future.

All agronomic and economic data were statistically analyzed using analysis of variance procedures (SAS Institute, Inc. 1985). Linear contrast analysis and Duncan's New Multiple Range Test were used to compare treatment means.

RESULTS AND DISCUSSION

Weather Conditions

The amount of precipitation that fell during the establishment year, for each sod-seeding experiment, was 16% to 22% above normal for experiments 2 and 4, and 6% to 15% below normal for the other two experiments (Table 1). These varied weather conditions are typical of what producers can expect in Saskatchewan. During the same time period, the average monthly temperature from April to October was close to normal, not deviating by more than 1.2 °C.

When precipitation that was received during April to June was used to describe the growing season, variations in amount and distribution were more extreme, than when annual precipitation amounts were considered. Thus, two experiments were started during drought years and two experiments were started during years when moisture was plentiful. Temperature during the April to June growing season was usually within 1 °C of the 30 year mean for the area, except in 1980 when the average was 3.4 °C above normal.

After the last of the four experiments was seeded there was a prolonged period of below normal

Table 4. Number of established alfalfa plants averaged over six years

No.	Treatments	Experiment number				Mean
		1	2	3	4	
		(Plants meter-row^{-1})				
1	Control	6	10	2	8	7
2	GLY2.5	9	15	6	12	10
3	GLY2.0NHS1.7†	9	11	4	14	10
4	GLY1.0NHS1.7†	9	12	6	13	10
5	Rotovate	10	4	5	10	7
	Mean (LSD = 3.2)	8	10	5	11	
Contrast:	Control vs Other treatments					**
	Rotovate vs Chemical treatments					**

† Plus Agsurf applied at 0.5% by volume.
** Indicates significance at 1% level, NS = nonsignificant.

precipitation that lasted from 1985 to 1988 (Table 1).

Forage Establishment and Yield

The number of alfalfa seedlings established was greater when glyphosate or rotovation was used to reduce competition from the resident vegetation than when alfalfa was sod-seeded directly into the control plots (Table 4). Also, the established population of alfalfa plants was greater following glyphosate than a rotovation treatment. If it is assumed that alfalfa should comprise 30% to 40% of the vegetation (Vallentine 1990), then the size of the alfalfa population should be approximately 1 to 2 plants per meter-row. This calculation was based on a suggested population of 11 plants m^{-2} for a grass-legume forage stand located in Saskatchewan, which is approximately 3 to 4 plants per meter-row, when the rows are spaced 30 cm apart (Anonymous 1987). Therefore, the alfalfa populations, which established in the experiments, were adequate in all years.

Alfalfa establishment was better in experiments that were started during moist as opposed to dry years (Tables 1 and 4). When the number of established alfalfa plants was correlated with precipitation, that fell during the calendar year, April to June, May to June and the month of June, the highest correlation ($r=0.9$, $P < 0.1$) was obtained with June precipitation for the glyphosate + ammonium sulfate treatment applied at 1.1 + 1.7 kg ha^{-1}. It is reasonable that successful alfalfa establishment is associated with years of highest precipitation during the period of most rapid plant growth. However, this is of little use to producers who must decide on when to sod-seed during April and May.

The number of brome plants per meter-row was higher following a herbicide or rotovation treatment than on the sod-seeded control plots

Table 5. Number of established brome plants averaged over six years

No.	Treatments	Experiment number 3	4	Mean
		(Plants meter-row^{-1})		
1	Control	2	8	5
2	GLY2.5	6	12	9
3	GLY2.0NHS1.7†	4	14	9
4	GLY1.0NHS1.7†	6	13	10
5	Rotovate	5	10	8
	Mean (LSD = 2.8)	5	11	
	Contrast Control vs Other treatments			**

† Plus Agsurf applied at 0.5% by volume.
** Indicates significance at 1% level, NS = nonsignificant.

(Table 5). Similar to alfalfa establishment, fewer brome plants established in experiments that were started during dry than wet years. Assuming a brome plant population similar to alfalfa is desirable, then the brome population was adequate in all experiments.

Alfalfa production in subsequent years appeared to depend on the level of precipitation that fell during the year of seedling establishment. When averaged over all treatments, the highest herbage production of alfalfa was recorded for the experiment (Exp. 2) which had the highest amount of precipitation recorded during the year of seedling establishment (Table 2 and 6). The experiment (Exp. 3) with the lowest production of alfalfa had the second lowest amount of precipitation recorded during the seedling year. When alfalfa production was correlated with amount of precipitation received during portions of the growing season (April to June, May to June, and June) the highest correlation (r=0.52) was with precipitation which was received during April to June. However, the year following seeding can influence long-term forage production. For example, experiment 1 was started during a dry year, followed by a moist growing season, while experiment 4 was started during a wet year, followed by below normal precipitation in subsequent years. Under these conditions, the alfalfa yields were generally intermediate to those recorded in experiments 2 and 3.

What is considered to be successful establishment of alfalfa, depends on yield and the management objective of the producer. If the objective is to minimize bloat in cattle, then alfalfa should not exceed 30% to 40% of the herbage production in a stand (Vallentine 1990). For managers who adhere to these guidelines, alfalfa production was more than adequate for three of four experiments, when the legume was sod-seeded without

Table 6. Alfalfa, grass and total herbage production averaged over the third to sixth year

No. Treatments	Experiment number				Mean
	1	2	3	4	
			(kg ha^{-1})		
Alfalfa					
1 Control	1608	2026	340	1175	1287
2 GLY2.5	2381	3142	690	1677	1973
3 GLY2.0NHS1.7†	2155	2399	420	1443	1604
4 GLY1.0NHS1.7†	2183	2512	722	1351	1692
5 Rotovate	1863	2349	497	1602	1578
Mean (LSD =761, P = 0.05)	2038	2486	534	1450	
Contrast: Control vs Other treatments					**
Contrast: Trt 2 vs Trt 3 and 4					*
Grass					
1 Control	560	1321	608	504	748
2 GLY2.5	682	1347	693	926	912
3 GLY2.0NHS1.7†	677	1465	907	913	990
4 GLY1.0NHS1.7†	654	1799	993	787	1058
5 Rotovate	754	1570	892	1127	1086
Mean (LSD =340, P = 0.05)	665	1500	818	851	
Contrast: Control vs Other treatments					**
Total production (alfalfa, grass and forbs)					
1 Control	2406	3498	1226	1843	2243
2 GLY2.5	3258	4654	1568	2696	3044
3 GLY2.0NHS1.7†	3067	4058	1507	2471	2776
4 GLY1.0NHS1.7†	3047	4481	1873	2273	2918
5 Rotovate	2843	4109	1561	2800	2828
Mean (LSD =995,P = 0.05)	2924	4160	1547	2417	
Contrast: Control vs Other treatments					**

† Plus Agsurf applied at 0.5% by volume.

*, ** Indicates significance at 5 and 1% levels, respectively.

Table 7. Brome herbage production averaged over the third to sixth year

No.	Treatments	Experiment number 3	4	Mean
	Brome			
1	Control	28	153	91
2	GLY2.5	438	544	491
3	GLY2.0NHS1.7†	436	385	410
4	GLY1.0NHS1.7†	637	463	550
5	Rotovate	526	698	612
	Mean	413	449	
	Contrast: Control vs Other treatments			**
	Bluegrass			
1	Control	579	350	465
2	GLY2.5	255	382	319
3	GLY2.0NHS1.7†	471	528	499
4	GLY1.0NHS1.7†	356	325	341
5	Rotovate	367	429	398
	Mean	406	403	
	Contrast: Control vs Other treatments			NS

† Plus Agsurf applied at 0.5% by volume.
** Indicates significance at 1% level, NS = nonsignificant.

the use of glyphosate. Managers who want more alfalfa in their pastures should consider using a herbicide or rotovation treatment to reduce the competition from the resident vegetation before sod-seeding. Rotovation leaves the soil prone to erosion and is not as desirable as glyphosate for reducing competition from the resident vegetation. Managers who want to maximize herbage production of alfalfa should use a high rate of glyphosate.

Grass herbage production was highest in the experiment (Exp. 2) which was started during the wettest year, and was lowest in the experiment (Exp. 1) which was started during the driest year (Table 6). Herbage production of grass was lower on the control than on the areas treated with a herbicide or with rotovation. When the grass component was separated into brome and other grasses, which were mainly bluegrass, the herbage production of brome was higher for the herbicide and rotovation treatments than for the sod-seeded control plots (Table 7). These results suggest that competition from the existing vegetation must be reduced before brome can be successfully established. Brome herbage production was similar on both experiments even though experiment 3 was started during a dry year and experiment 4 was started during a wet year.

The average herbage production for the bluegrasses was similar in experiments 3 and 4, and for all treatments. None of the herbicide or mechanical treatments, which were used to reduce competition from the resident vegetation, affected the long-term yield of the bluegrasses.

The contribution of forbs to total production ranged from 4% to 13% of the dry weight, and was statistically similar for treatments and experiments (data not presented). The dry weight of the woody plants was 1% or less of the total production for each of the experiments and was also statistically similar for experiments and treatments (data not presented).

Total herbage production of alfalfa, grass, plus forbs ranged from 1547 to 4160 kg ha^{-1}, when averaged over all treatments and years (Table 6). As expected, the highest total production was recorded for experiment 2, which was started during the wettest year, while experiment 3, which was started during a dry year, had the lowest total production.

Economic Returns

The NPVs for the sod-seeding treatments (Table 8) were positive under most economic scenarios, implying that the discounted returns from the consumable portion of herbage more than covered the costs of forage establishment. However, these results do not indicate whether sod-seeding is more or less profitable than no pasture improvement because the experiments lacked inclusion of this latter benchmark.

The NPVs were significantly influenced ($P<0.05$) by the year in which the pasture improvement practices were initiated (Table 9), but within an experiment, there was often little difference in profitability among sod-seeding treatments. Further, there was no significant ($P>0.10$) interaction of experiments and sod-seeding treatments. As for findings on plant establishment and herbage production, the NPVs for the sod-seeding treatments were highest when they were initiated in wet years and lowest when initiated in dry years. Changes in the imputed value of forage and in the nature of the future forage yield benefits influenced the NPVs in absolute terms, but had little affect on the relative rankings of the treatments. Only when forage values were very high and the benefits of pasture improvement were expected to continue into the future, were the NPVs greater ($P<0.05$) for treatments that used glyphosate applied alone at 2.5 kg ha^{-1},or at 1.0 kg ha^{-1} plus NH_4SO_4 at 1.7 kg ha^{-1}, than for the control.

CONCLUSIONS

The most important factor contributing to the success of sod-seeding is the availability of adequate moisture. Alfalfa establishment was correlated with the amount of precipitation that fell during June and herbage production was correlated with precipitation that fell during

Table 8. Net Present Values for sod-seeding treatments

Forage value Treatment	Four-Years only	Constant future effect 5-Years	Constant future effect 10-Years	Declining future effect 5-Years	Declining future effect 10-Years
			($ ha^{-1})		
Low forage values					
1 Control	45a†	133a	202a	99a	138a
2 GLY2.5	66a	131a	230a	84a	138a
3 GLY2.0NHS1.7	-4b	108a	195a	65a	113a
4 GLY1.0NHS1.7	40a	158a	250a	112a	164a
5 Rotovate	25ab	138a	227a	95a	144a
Mean	22	134	221	91	139
Sx	10.9	18.6	24.6	15.7	19.0
Medium forage values					
1 Control	169a	345a	482a	278a	354a
2 GLY2.5	184a	435a	631a	339a	448a
3 GLY2.0NHS1.7	154a	377a	551a	292a	389a
4 GLY1.0NHS1.7	207a	442a	626a	352a	455a
5 Rotovate	185a	412a	590a	326a	424a
Mean	180	402	576	317	414
Sx	21.9	37.2	49.3	31.4	38.1
High forage values					
1 Control	293a	556b	763b	456b	570b
2 GLY2.5	362a	738a	1033a	595a	758a
3 GLY2.0NHS1.7	312a	646ab	908ab	519ab	664ab
4 GLY1.0NHS1.7	374a	727a	1004a	593a	746a
5 Rotovate	346a	686a	953ab	557ab	704ab
Mean	337	671	932	544	688
Sx	32.9	55.8	73.9	47.1	57.1

† Values within a column for each forage price level, followed by the same letters, do not differ significantly (P>0.10) according to Duncan's New Multiple Range Test.

April to June of the seeding year. Producers considering sod-seeding should seed early in the spring during those years when soil moisture conditions are favourable. The most practical treatment for producers is to seed alfalfa into the sod with a triple-disc drill equipped with depth control bands that allow precision seeding. It is extremely important to seed small legume seeds at a shallow depth early in the spring. When alfalfa is sod-seeded without soil disturbance, there is little risk of creating weed or erosion problems. Should seedling establishment fail, then the technique can be repeated during

Table 9. Mean Net Present Values for sod-seeding by experiment

Forage value Treatment	Four-Years only	Constant future Effect 5-Years	Constant future Effect 10-Years	Declining Future Effect 5-Years	Declining Future Effect 10-Years
			($ ha^{-1})		
Low forage values					
Exp. 1	34b†	154b	248b	109b	161b
Exp. 2	105a	276a	409a	211a	284a
Exp. 3	-56d	0d	43d	-21d	3d
Exp. 4	6c	105c	182c	67c	110c
Mean	22	134	221	92	140
Sx	9.8	16.7	22.0	14.1	17.0
Medium forage value					
Exp. 1	204b	444b	632b	353b	457b
Exp. 2	346a	678a	954a	557a	704a
Exp. 3	23d	134d	220d	92d	140d
Exp.4	146c	344c	499c	269c	355c
Mean	180	402	476	318	414
Sx	19.6	33.3	44.1	28.2	34.1
High forage value					
Exp. 1	374b	734b	1016b	597b	753b
Exp.	587a	1098a	1498a	903a	1124a
Exp.	102d	268d	398d	205d	277d
Exp.	296c	734c	816c	470c	599c
Mean	337	709	932	544	688
Sx	29.4	50.0	66.1	42.2	51.1

† Values within a column for each forage price level, followed by the same letters, do not differ significantly (P>0.10) according to Duncan's New Multiple Range Test.

successive springs until an adequate stand of alfalfa is obtained.

Further, the results indicate that producers who have already made a decision to improve pasture productivity through seeding of tame forages may find it equally or more economical to substitute sod-seeding without herbicide, or sod-seeding in combination with an application of glyphosate to suppress existing vegetation, in place of the traditional method of breaking the land and then reseeding. This technique has only been tested on poor condition pastures in the Aspen Parkland that contain a high percentage of bluegrasses.

REFERENCES

Anonymous. 1981. Canadian climate normals 1951 - 1980, temperature and precipitation, Prairie Provinces. Publ. by Environment Canada, 4905 Dufferin Street, Downsview, Ontario.

Anonymous. 1987. Guide to farm practice in Saskatchewan Revised 1987. Publ.. by the University of Saskatchewan, Saskatoon, Saskatchewan.

Baird, D. D., Upchurch, W. B., Homesley, W. B. and Franz, J. E. 1971. Introduction of a new broad spectrum postemergence herbicide class with utility for herbaceous weed control. Proc. 26th N. Central Weed Control Conf. 64-68.

Bowes, G. G. and G. Friesen. 1967. The use of paraquat to improve pastures in Manitoba. Weeds 15:241-243.

Doll, J.P. and Orazem, F. 1978. Production economics: theory applications. Grid, Inc., Columbus, Ohio. 406 pp.

Mitchell, J. H., Moss, H. C. and Clayton, J. S. 1944. Soil survey of southern Saskatchewan. Soil survey of Saskatchewan Rep. No. 12, Univ. Forestry Ser. Pub. No. 1300.

Perry, T. W. 1980. Beef cattle feeding and nutrition. Academic Press, New York. 383 pp.

Rowe, J.S. 1972. Forest regions of Canada. Dep. Environment. Can. Forest Serv. Pub. No. 1397.

Saskatchewan Agriculture and Food. 1990. Farm machinery custom and rental rate guide 1990. Economics Branch, Saskatchewan Agriculture and Food, Regina, Sask., March, 35 pp.

Smoliak, S., Willms, W.D., Wroe, R.A., Adams, B.A. and Ehlert, G. 1988. Range pastures in Alberta. Publ. No. Agdex 134/14-8, Alberta Agriculture, Edmonton, Alberta.

Statistical Analysis System Institute Inc. 1985. SAS user's guide: statistics version 5th ed. SAS Institute Inc., N.C., 956 pp.

University of Saskatchewan. 1990. Saskatchewan farm input price survey report no. 100. Department of Agricultural Economics, University of Saskatchewan, Saskatoon, Sask. March 14, 4 pp.

Vallentine, J.F. 1990. Grazing management. Academic Press. New York, N.Y. 533pp.

Waddington, J. and Bowern, K. E. 1976. Pasture renovation by direct drilling after weed control and sward suppression by herbicides. Can. J. Plant Sci. 56: 985-988.